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Assessing Sediment Quality in Water Bodies Associated with Manufactured Gas Plant Sites

Sediment Management and Remediation Techniques Program
and
Environmental Repair Program

Wisconsin Department of Natural Resources

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Box 7921
101 South Webster Street
Madison, Wisconsin 53707-7921
TELEPHONE 608-266-2621
FAX 608-267-3579
TDD 608-267-6897

March, 1996

SUBJECT: Assessing Sediment Quality in Water Bodies Associated with Manufactured Gas Plant Sites

Dear Interested Citizen:

The primary goal of this guidance on "Assessing Sediment Quality Associated with Manufactured Gas Plant Sites" is to provide a framework for investigating potential surface water problems at locations of manufactured gas plants (MGPs). This guidance is intended for use by Wisconsin Department of Natural Resources staff, utilities and other groups concerned with MGP properties, and their consultants.

This guidance consists of the following sections:

1. Introduction to potential sediment contamination problems associated with MGP sites;
2. Discussion of the contaminants of concern from MGP waste and by-products;
3. Overview of aquatic sediment site investigations;
4. Discussion of how to scope an investigation and prepare work plans;
5. Description of goals and activities of an initial field investigation;
6. Description of goals and activities of a detailed field investigation;
7. Discussion of evaluating the significance of MGP sediments;
8. Brief discussion of how to identify, evaluate, and select remedial options;
9. Brief discussion of remediation and post-remediation monitoring; and
10. Discussion of the case closure process.

This guidance outlines a flexible process that allows for site-specific assessment designs, data evaluation, and contaminated sediment management decisions. By implementing this guidance and fostering effective communication among all parties involved in MGP assessments, we hope to assure quality assessments that support appropriate contaminated site management decisions.

Sincerely,

Susan Sylvester

Susan L. Sylvester
Administrator
Division for Environmental Quality

Acknowledgements

This guidance was prepared by Tom Janisch and Scott Redman of the Sediment Management and Remediation Techniques Program with the assistance of Bob Strous and Carol McCurry of the Environmental Repair Program. Jim Reyburn of Lake Michigan District, and Margaret Graefe of Southeast District.

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1. Introduction

1.1 Need for Surface Water Investigations at Manufactured Gas Plant Sites

Many of the manufactured gas plant (MGP) sites in Wisconsin were located near or adjacent to rivers, streams, impoundments, or lakes. Surface waters were important for these plants as they provided an economical method of delivering coal to the plant, a source of water required in various manufacturing processes, and a means of disposal, either intentional or unintentional, of wastes or by-products of coal gasification. Disposal of MGP wastes in or adjacent to Wisconsin's surface waters occurred prior to the regulation of discharges to Wisconsin's waters. Nonetheless, MGP wastes are comprised of mixtures of organic and inorganic substances that can adversely affect water quality and are a potential concern even today in the state's surface waters.

In the 40 to 50 years that have passed since the operation of MGPs, one might expect that wastes from these plants would have been degraded, transported, dissipated, or buried under recently deposited sediments over time. However, investigations and monitoring of water bodies adjacent to a few MGP sites have shown elevated levels of MGP contaminants in surficial sediments and at considerable depth below the sediment surface. Where contaminants are present in surficial sediments, there is a potential for release of contaminants into the overlying water column. MGP contaminants in surface sediments have the potential to cause mortality or sublethal toxic effects of benthic and water column organisms, to lead to fish neoplasms and other adverse effects, and to threaten human health through recreation, drinking water, and food chain exposures to MGP contaminants.

1.2 Sediment Contamination Typical of MGP Sites

In the worst cases observed to date in Wisconsin, water bodies near two MGP sites were found to have total PAH concentrations of 3,600 and 11,890 mg/kg in surface sediments. Coal tar contaminated sediments and free coal tar oils have been observed at the sediment surface on the river bottoms and extending to 12 to 15 feet in depth at some sampling locations. MGP site-related contaminated sediments have been found as far as 400 to 2,500 feet downstream from MGP sites.

Depending upon the amount of urbanization and industry associated with a water body, PAH concentrations in sediment are expected to vary. In areas not affected by specific contaminant sources, PAH concentrations in sediment generally do not exceed 10 mg/kg and are typically in the range of 2 to 5 mg/kg or less. Persaud et al. (1993) estimate that adverse effects to benthic invertebrates are associated with total PAH concentrations as low as 4 mg/kg and severe effects are associated with PAH concentrations of 500 mg/kg (assumes 5% total organic carbon content in the sediments). At this severe effect level, the majority of benthic species would be detrimentally affected. Increasing effects would be expected as concentrations increase from the low effect level of 4 mg/kg to the severe effect level of 500 mg/kg.

Sediment quality guidelines have been developed specifically to protect aquatic resources. Consequently, these guidelines are likely to be different than soil cleanup criteria developed to protect ground water and human health. Soil cleanup criteria will be discussed in separate WDNR guidance. Although there may be instances where soil cleanup will be based on sediment quality guidelines (i.e., if there is a direct pathway for erosion of soils to sediment deposits), soil cleanup criteria will not be applied to sediment cleanups.

In addition to PAHs, other contaminants of concern in the sediments near MGP sites include metals, cyanide, phenols, and volatile organic compounds. Chapter 2 discusses MGP wastes and contaminants.

1.3 Purpose and Scope of this Guidance

Given the potential threats posed by MGP contaminants in surface waters, site investigations at MGP sites should include evaluations of sediment quality in surface waters near and adjacent to these sites. The purpose of this guidance is to provide a framework for sediment investigations at MGP sites. This guidance should be used by WDNR, utilities, and consultants when planning investigations and when reviewing investigation work plans and reports.

This guidance describes a multi-step process to be used, with case-specific modification as may be appropriate, to conduct and document the results of file reviews, field investigations, and data evaluations to characterize the nature and extent of MGP site-related sediment contamination. This guidance should be used in conjunction with applicable administrative rules and other appropriate WDNR guidance, including

- Guidance for Analytical Characterization of Sediment, Soil, and Surface and Ground Water at Manufactured Gas Plant Sites (in draft);
- Chapters NR 716 and 722, Wis. Adm. Code and WDNR guidance on implementation of these rules;
- Guidance for Contaminated Sediment Clean-up Decisions in Wisconsin (in draft); and
- Guidance on Assessing Ecological Impacts and Threats from Contaminated Sediments (1992).

2. Contaminants of Concern from Manufactured Gas Plant Waste and By-Products

2.1 MGP Wastes and By-Products

Lee et al. (1992) report that more than 11 billion gallons of coal tar were generated at MGP sites in the U.S. during the years 1816 to 1947 and that the disposition of several billion gallons is unknown and remains unaccounted for. The types and quantities of waste discharged to surface waters from MGPs vary from site to site. The contaminant content of soil, groundwater, surface water, and sediments at MGP sites depend on the plants' manufacturing processes, feedstocks (e.g. coal, crude oil, naphtha), and disposal practices (which were largely unregulated during the period of active gas production) (U.S. EPA, 1988).

Free organic tars, oils, lamp black, cinders, coke, ash, and coal particles and fines may all have been released to surface waters adjacent to or near an MGP site. Hereafter, cinders, coke, and ash particles and fines will be referred to as coal materials (as distinguished from coal tars and other gasification wastes). Coal tars, a by-product of the gasification of a coal feedstock, are complex mixtures of numerous (i.e., over 10,000) organic compounds of varying molecular weight, functional groups, and characteristics. Coal materials, coal tars, and other MGP wastes can contain high concentrations of toxic compounds and can physically impair the habitat quality of the sediment substrate.

Toxic compounds from MGP wastes may tend to be associated with bottom materials but can be released into the water column — in dissolved form, as suspended matter, or as separate non-aqueous phases — where they are more mobile and bioavailable and may potentially lead to widespread threats to the health of aquatic organisms and humans.

2.2 Chemicals of Concern at MGP Sites

Various lists of common chemicals of concern at MGP sites have been compiled based on the chemical content of the waste and by-products from the gas manufacturing processes. Table 1 is a list of coal-associated inorganic elements and organic compounds that are of regulatory concern and for which standardized analytical methods have been established. This list, divided into six chemical groups, represents those chemicals that are most likely to be present in wastes and wastewater derived from coal handling and coal gasification. Among these compounds, concentrations can vary significantly from one MGP site to another.

In addition to the compounds that can be readily analyzed, numerous other related compounds are found in all coal tars. According to Lee et al. (1992), less than 40% (on a mass basis) of coal tar constituents can be quantified using common organic chemistry extraction and chromatographic techniques. The fraction of coal tar that cannot be identified by typical analyses is often referred to as "pitch" (Lee et al., 1992). The majority of the constituents of pitch are aromatic compounds with high molecular weights and relatively low aqueous solubilities. In addition to the compounds listed in Table 1, MGP sites may be contaminated with heterocyclic organic compounds containing nitrogen (quinolines, acridenes, carbazoles), sulphur (thiopenes), and oxygen (dibenzofuran) as well as cresols and many alkyl-substituted PAH compounds.

The pitch fraction of coal tar is significant for two reasons. First, biological organisms can be exposed to and suffer adverse impacts as a result of exposure to pitch constituents. Studies of coal tar/water partitioning relationships have found that most of the neutral fraction organic

Table 1
Coal-Derived Chemicals

Conventional	Inorganics	Metals	Volatile Aromatics	Phenolics	PAHs
pH 5 Day BOD Chemical Oxygen Demand Total Organic Carbon Total Suspended Solids Oil and Grease Phenols (4-AAP)	Ammonia Cyanide Nitrate Sulfate Sulfide Thiocyanates	Aluminum Antimony Arsenic Barium Cadmium Chromium Copper Iron Lead Manganese Mercury Nickel Selenium Silver Vanadium Zinc	Benzene Ethylbenzene Toluene Total Xylene	Phenol 2-Methylphenol 4-Methylphenol 2,4 - Dimethyl-phenol	Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(g,h,i)perylene Benzo(k)fluoranthene Chrysene Dibenzo(a,h)anthracene Fluoranthene Naphthalene Indeno(1,2,3-c,d)pyrene Phenanthrene Pyrene

compounds present in the coal tar phase are also detected in the aqueous phase (Rostad et al., 1985). Although many larger molecular weight and neutral organic compounds are considered to be relatively insoluble, they will still enter the aqueous phase to the extent of their limited solubility. Many of these compounds are of concern because of their suspected mutagenic and/or carcinogenic properties (i.e., similar to unsubstituted PAHs). Second, the presence of pitch can influence the rates of release and partitioning of the more soluble constituents of coal tar (e.g., BTEX, naphthalenes).

The 15 unsubstituted PAH compounds listed in Table 1 serve, in essence, as an indicator list for the complex mixture of aromatic compounds that are present in coal tars and other MGP wastes. As a simplifying assumption, WDNR suggests that parent PAH compounds and any of the untested MGP contaminants are generally co-located. If remedial action levels are based on the parent PAHs, it is assumed that the other MGP contaminants will be concurrently addressed. Checks on this assumption may be needed in post-remediation monitoring by using toxicity tests (e.g., Microtox or Mutatox) or contaminant exposure tests (e.g., EROD induction) to determine if all significant toxicity or exposure has been removed in the sediments by PAH-driven action levels.

Nitrogen in the coal feedstocks of MGPs led to the formation of cyanide compounds in the raw product gas. These cyanide compounds were removed from the produced gas during the gas manufacturing process and are present in spent oxide wastes at some MGP sites. Spent oxides, also referred to as Prussian Blue, have a characteristic blue color.

3. Aquatic Sediment Investigations at MGP Sites — Overview

WDNR recommends that investigations of surface water and sediments at MGP sites should proceed through a number of steps. A stepped process is recommended so that information collected as the investigation progresses can be used (1) to establish the need, if any, to proceed to subsequent, more detailed steps and (2) to scope and design the activities of those steps.

In this guidance, WDNR is recommending a consistent approach to evaluating sediment and surface water contamination at MGP sites. *Given the different characteristics that may be associated with each site, a single investigatory and sampling design will not be appropriate for all sites.* The recommendations that follow address the information needs and ways to collect that information. The *details* of specific investigatory and sampling designs will need to be developed on a site specific basis by the investigating parties.

Depending on the WDNR's involvement in the project, the details of each proposed investigatory step should be discussed with, or reviewed and approved by, WDNR prior to implementation. The investigators should evaluate the data and results of each step and document the findings of the step in a report, which may be reviewed by WDNR if the site is project managed by WDNR. If WDNR is actively involved in project oversight, the investigating party and WDNR can then come to agreement on the next step of investigation or site management.

The recommendations in the following chapters address sediments and surface water. It is expected that soil and groundwater contamination will be addressed under the on-land investigations. (Investigations of soil and ground-water contamination should follow the procedures outlined in chs. NR 716 and 140, Wis. Adm. Code and any relevant guidance developed pursuant to those administrative rules.) Possible on-land sources and pathways of contaminant transport from soils and groundwater to surface water need to be eliminated to ensure that they are no longer loading contaminants to the aquatic system. Continuing contaminant loads from the MGP site may recontaminate any areas of the surface water that are remediated prior to control of on-land or upstream sources.

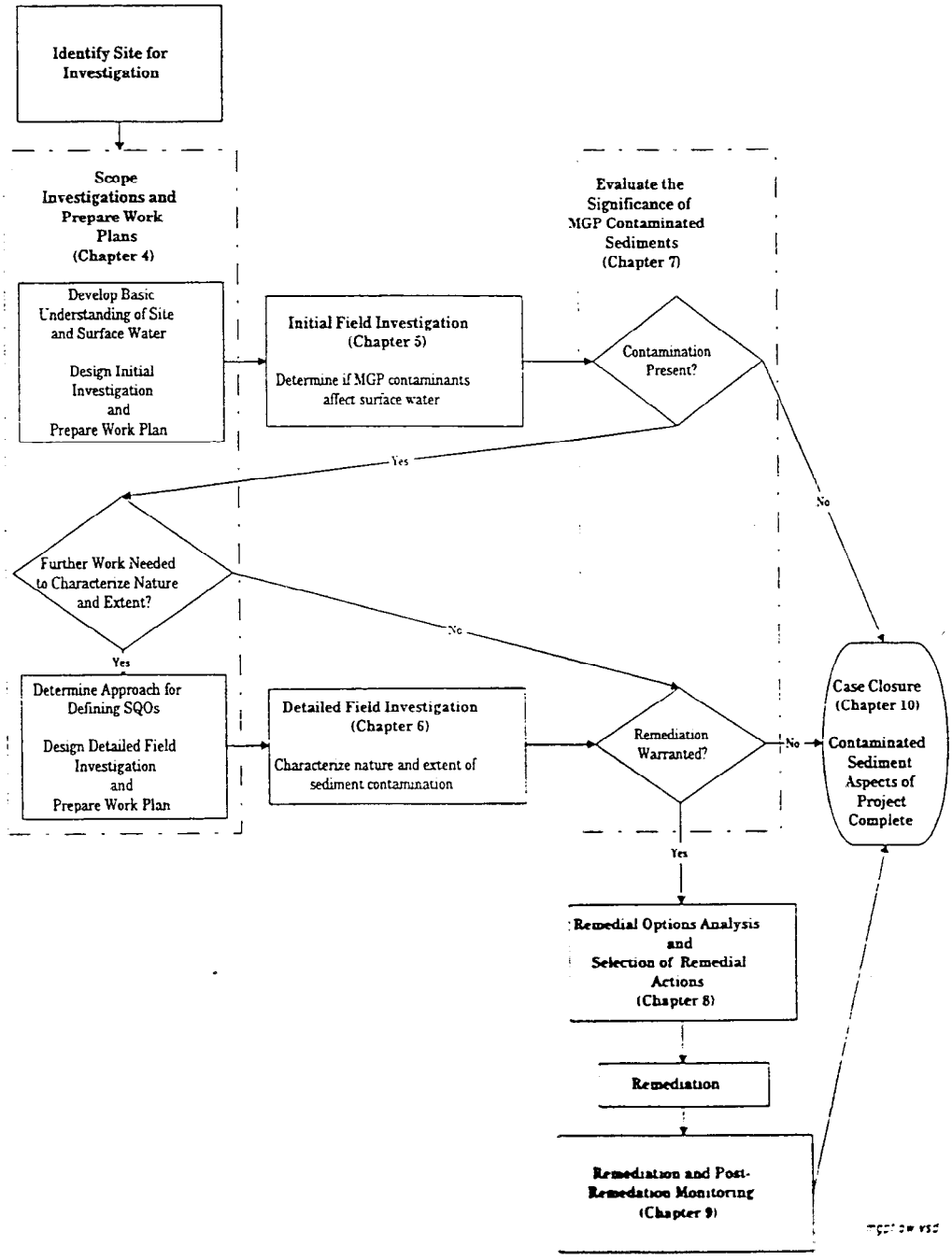
As illustrated in Figure 1, WDNR recommends that MGP site sediment investigations consist of an initial field investigation and, if needed, a detailed field investigation both incorporating the following elements.

- First, the scope and design of the field investigations should be determined and work plans prepared. This element is discussed in Chapter 4.
- Second, field investigations should be conducted. This element is discussed in Chapters 5 and 6 (initial and detailed investigations, respectively).
- Finally, field investigation data on sediment quality should be evaluated and sediment characterization reports prepared. The evaluation of sediment quality data is discussed in Chapter 7.

The initial field investigation should include reconnaissance probing and sampling of the water body. Sediment quality data from this investigation should be reviewed in a limited quantitative assessment. The goal of this investigation is to determine if any MGP contaminants are present in the surface water.

A detailed field investigation should be carried out where the initial investigation identifies sediment contamination that potentially threatens water quality. The goal of the detailed investigation is to determine the extent and magnitude of MGP contamination in the sediments and water.

Figure 1
Investigation of Sediments at MGP Sites -- A Multi-Step Process



To interpret the results of either the initial or detailed investigation, the investigator should evaluate of the significance of sediment contamination to ecosystem and human health. This analysis should quantify or otherwise characterize the adverse impacts and risks posed by MGP contaminants, especially focused on ecological impacts and risks.

After site conditions have been adequately characterized and evaluated in a detailed analysis, the investigating party should perform a remedial options analysis, select a remedy, and, if needed, conduct an active clean up. Alternatively, an initial field investigation or a remedial options analysis may indicate that no active clean up is needed. In any case the selected remedy should be documented. Chapter 8 discusses remedial option analysis and remedy selection.

Remediation and post-remediation monitoring should be conducted to ensure that the actions undertaken are protective of the environment. Chapter 9 presents some brief, general guidance for remediation and post-remediation monitoring.

Remediations of contaminated sites are "closed out" by WDNR when it is documented that all standards are met and that contamination no longer poses a threat to human health or the environment. Chapter 10 briefly discusses WDNR's case closure process and the information that should be submitted for WDNR review to facilitate case closure.

4. Scoping the Investigation and Preparing Work Plans

4.1 Developing an Understanding of the MGP Site and Adjacent or Nearby Surface Waters

The purpose of these tasks is to develop an understanding of the MGP site to support appropriate, detailed plans for field investigations. WDNR recommends that efforts to develop this understanding should begin with some fundamental information about the site:

- What are the characteristics of the water body associated with the site? Specifically, what are the hydrodynamic and bathymetric characteristics of the surface waters that may affect transport and distribution of any MGP wastes that may have entered the water body?
- What is known about the historical shoreline and surface water activities in the vicinity of the site?
- Where were historical discharges and where are current discharges to the water body, including any (potential) discharges from the MGP site?
- What gasification processes were carried out at the plant? What products, by-products, and wastes were produced and at what rates?
- Has (contaminated) groundwater (potentially) discharged to surface waters from the site? If so, what wastes or contaminants, at what rates, and in what amounts?
- Were wastes (potentially) discharged to surface waters? If so, what wastes and in what amounts?
- What conditions may have occurred to influence the transport of MGP site contaminants to surface water sediments and affect the chemical, physical, and biological weathering of MGP site contaminants in the sediments?

Information to answer these questions may be found in plant operating records, which may be in the possession of the current property owner or the corporate entity which operated, or is the successor to the operator of, the MGP. Other information sources that may be useful, especially in providing information on the surface waters and historical conditions, include historical maps and aerial photos; water resources management plans from WDNR and/or local planning agencies; reports on dredging projects in the vicinity of the site (check with U.S. Army Corps of Engineers); and WDNR files on permits to discharge to or fill surface waters.

Water Body Characteristics. Characteristics of the water body associated with the site should be established and reported. Such information should include:

- Type of waterbody - impoundment, lake, stream, river;
- Average annual flow rate and/or typical water velocities (for flowing systems);
- Flood stage levels;
- River width and cross-sectional area or lake surface area, volume, and general bathymetric characteristics -- if available, provide bathymetric maps or water depth data normalized to a common datum for the site;
- Design and operating characteristics of downstream dams or water control structures;
- General characteristics of the bed of the water body, including sediment particle size distribution and aquatic plant distribution and communities;

- Location and description of wetlands in the vicinity of the site;

- Available information on sediment transport and deposition in the vicinity of the site;

Shoreline Character and Alterations. During the long period of time between initial operation of an MGP to the present day, considerable alterations in land use and character may have taken place on land and in the surface waters in the vicinity of MGP sites. The following information may be helpful in developing a plan for site investigations:

- Historical shoreline configuration associated with the plant site, plant buildings, water intakes, discharge lines, and other relevant infrastructure;

- Location and time of any shoreline bank changes due to erosion or filling, construction of bulkheads, sheet pile retaining walls, shoreline riprapping, and placement of any type of fill behind the structures;

- Location of any filled sloughs, low areas, wet areas, and drainage ways at or near the site; and

- Alterations of water levels, channels, or flow characteristics by construction or changes in operation of dams or other control structures.

Historical and Current Dischargers. Possible contaminant sources, including the potential discharge from the MGP site should be generally characterized. Sources other than the MGP site include dischargers in the immediate area and elsewhere in the watershed, including POTWs, industries, stormwater discharges, and other point and nonpoint sources. Sources (including petroleum storage areas, wood treatment facilities, coal storage areas or piles, coking operations, and coal ash storage or disposal areas) that may have potentially discharged contaminants such as PAHs, cyanide, metals, petroleum oils, or creosote to the surface waterbody should be identified.

Sediment and Surface Water Quality. Sediment and surface water sampling data obtained from offshore or downstream of an MGP site, or observations of oils or oil-stained sediment materials, may be available in reports or files from WDNR, local water quality planning agencies, researchers, and dischargers. Activities that may have generated historic data that may be useful in scoping the MGP site investigation include

- Offshore construction activity in the vicinity of the site (e.g. sewer or utility crossings, bridge or shoreline construction);

- Shoreline excavations at or near the site;

- Dredging and sediment characterization in preparation for dredging adjacent to or near the site (including navigational projects or the development and maintenance of marinas or other facilities); and

- Historic or ongoing condition, problem assessment, or evaluation monitoring of the surface water in the vicinity of the site.

Another potential source of information on the condition of the surface water is citizen complaints about the presence of contamination, slicks, or odors in the vicinity of an MGP site.

Reports from these activities should be reviewed for documentation of potential MGP site-related contamination and observations of oily sheens or oils on the water's surface (from bank seepage, bottom upwelling, or disturbance of the shoreline or bottom by barges, boats, off-shore construction, or other activities).

4.2 Designing Sediment Site Investigations

Using all available background information and a conceptual understanding of the site, sediment investigations at MGP sites should be designed to meet specific objectives. Typically, the objective of an initial field investigation should be to determine whether MGP site contaminants are present in potentially harmful concentrations in the aquatic system. Therefore, an initial field investigation should be designed to characterize contamination in areas that would be expected to be most severely contaminated by any releases from the MGP site to the nearby aquatic resource. Initial field investigations are discussed in Chapter 5.

A detailed field investigation is typically performed to characterize the nature and extent of MGP site-related contaminants in the aquatic environment. This investigation will typically involve a much more detailed assessment of contaminant distributions in the sediment than was performed for the initial investigation. In addition, the detailed evaluation may also include field efforts to support development of site-specific sediment quality objectives (SQOs).

Based on the study objectives and the available data, the investigating party should prepare a study design, characterizing the type and level of efforts to be conducted in the field investigation stage of the assessment. Study designs should be documented in work plans as discussed in the following section.

4.3 Site Investigation Work Plans

The results of the scoping step should be used to create a work plan for the performance of field investigations of sediment and surface water contamination at the MGP site. This work plan should contain the information specified in s. NR 716.09(2). Wis. Adm. Code, including:

- Site name, address, and location;
- Name and address of the investigating party and all consultants;
- Site location map;
- Information gathered during scoping of the project;
- Information on the physiographical and hydrological setting;
- Sampling and analysis strategy;
- Description of site management procedures; and
- Schedule for conducting investigations and reporting results to WDNR.

Work plans should be submitted to WDNR (for review and approval if WDNR is actively overseeing efforts at this site) prior to proceeding with field investigation activities.

The initial work plan should provide detailed information on the initial field investigation (Chapter 5) and provide at least a general description of proposed approach for evaluation of data from the initial investigation. Subsequent work plans for detailed field investigation, if any, may be needed after completion of the initial field investigation. These should also describe proposed field activities and data evaluation approaches.

5. Initial Field Investigation

Data collected in the initial field investigation should typically include determination of the area and volume of soft sediments in the vicinity of the MGP site, field characterization of sediments collected by dredge and core, and *limited* chemical and physical characterization from laboratory analysis. As described above, a work plan for this investigation should be submitted to WDNR (for review and approval if WDNR is actively overseeing project activities). Among other required contents, this plan should describe the standard operating procedures for sampling, equipment decontamination, sample handling and storage, analytical methods and quality control procedures, sample network design, a schedule for sampling and analysis activities, and the handling and disposal of investigative wastes.

5.1 Design of Initial Field Investigation

The sampling design for the initial field investigation of sediment contamination should incorporate transect lines established perpendicular to the site shoreline or radiating from the MGP site as shown in Figure 2. An unimpacted reference sediment site should be sampled and analyzed for comparison with the study site sample results. The reference site should be "upstream" or outside of the potential influence of any released waste streams or plumes from the MGP site to the surface water. Design of investigations of MGP facilities on tributaries to the Great Lakes or on flowages created by dams should recognize that there may exist some mixing "upstream" from the MGP site. The reference site should be selected to be representative of sediment quality in the area without any input from the MGP site.

For river and stream sites, the sediment impact zones from MGP contaminants may be assumed to extend as shown in Figure 2. The most highly contaminated sediments are expected in Zone 1. It is assumed that lower levels of MGP contaminants would occur in the sediments farther from shore or downriver in Zones 2 and 3. In the initial field investigation, unless other information is available, the sampling design should include minimal characterization of an area approximately 1,000 feet distant from the site. After sampling is underway, the distribution of MGP contaminants at the site may become apparent and the design of the sampling program (e.g., spacing between and along transects) may be adjusted at that time.

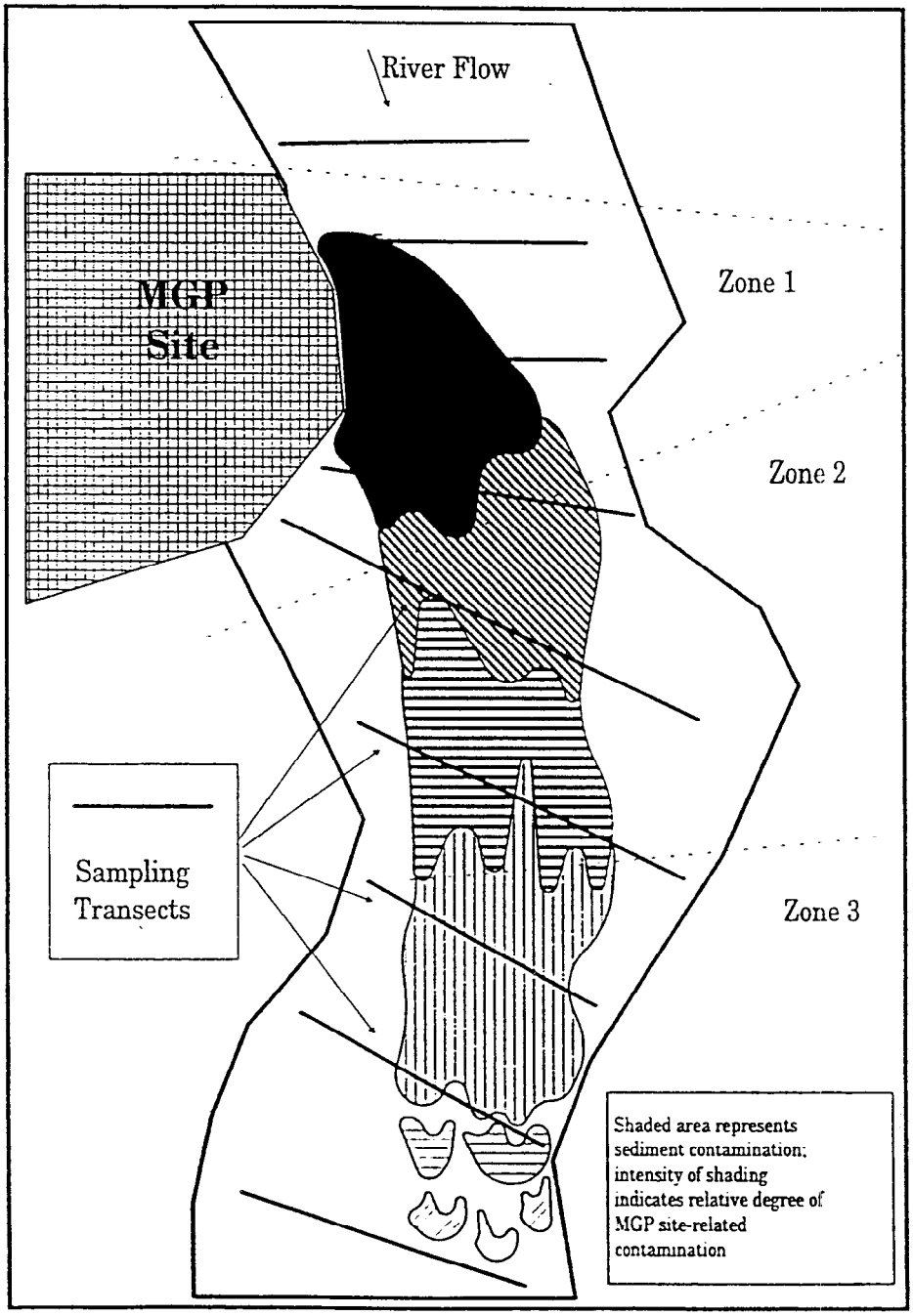
5.2 Occurrence and Depths of Soft Sediments

Information on water depths and thickness of deposits of soft sediment should be determined during the initial field investigation. This information may be collected by various methods, including sediment probing and a number of remote sensing approaches.

Thickness of deposited sediments can be found by probing with a sediment sounding pole at numerous points along a number of transects (e.g, at an interval of approximately one-tenth to one-twentieth of the distance across the water body). At each probing location, a sediment sounding pole is extended to the sediment surface, water depth is recorded, and the pole is then pushed into the sediments to the point of refusal. The difference between the initial water depth and a depth mark on the pole after pushing the pole into the sediments is an estimate of the thickness of "soft" unconsolidated sediment.

Because of the potentially large areas of contaminated sediments that may be associated with MGP sites, probing (and coring) may not provide a cost-effective method for fully characterizing areas and volumes of soft sediment. As an alternative to probing, a number of remote profiling approaches are also available for determining the thickness of soft sediments in surface

Figure 2
Schematic of MGP Site-Related Contamination in River Sediments



This figure presents a generalized concept of a possible pattern of contamination at an MGP site. The areal and vertical distribution of MGP site-related contaminants in the sediments of a surface water in the vicinity of an MGP site will depend on a number of site specific factors.

waters. Remote profiling approaches that can be used to characterize soft sediment extent and thickness include multiple frequency sonar, electrical resistivity, nuclear density probe, seismic echo sounding, and ground penetrating radar.

The investigating party should demonstrate to WDNR the resolution and utility of the technique to be used for soft sediment sediment mapping. The proposed survey design (i.e., number of survey lines, diagonal survey line intervals, number of tie points, etc.) should be defined in the work plan.

The most commonly applied remote profiling method is acoustic (sonar) mapping. This approach has been used in Wisconsin with rather poor results due to inability of the acoustic waves to penetrate gaseous sediment bodies.

Various methods may be appropriate for identifying and controlling locations in an initial field investigation (see Section 5.4).

5.3 Sediment Sample Collection

The quality of both surficial sediments and lower sediment strata should be characterized visually, physically, and chemically in the initial field investigation. Most samples taken in this phase of the assessment will be subject to visual characterization and screening-level chemical characterizations in the field. Relatively few samples will be subjected to laboratory analyses. Sampling of surficial sediments and sediment cores are discussed in the following subsections. Recommendations for field and laboratory characterization are discussed in Sections 5.5 and 5.6, respectively. As discussed in Section 5.7, care should be taken to minimize disturbances of contaminated materials and to contain and collect any sheens or slicks released during sample collection.

Surficial Sediments. Surficial sediment samples should be collected during the initial field investigation using a Petersen, Ponar or other comparable dredge collection device. The reason for taking surficial dredge samples is to determine if visible MGP contamination (e.g., residual coal tars or coal tar-contaminated sediments) is exposed in the top four to six inches of sediments, which is typically the biologically active zone.

Surface sediment samples should be taken by dredge along transects that start from shore just upstream of the site and extend out into the waterbody. Parallel or radiating transects should be set up, at intervals, adjacent to and downstream from the site. The distances between transects will depend on a number of factors, including the hydrologic characteristics of the surface water, the size of the water body and the MGP site, and available information about the possible areal extent of contamination. Mechanical sediment probing and/or sediment coring sites can be located between dredge sample transects to ensure adequate coverage of the area of interest during the initial field investigation.

At least three dredge samples should be collected along each transect. Distance between dredge samples along a transect should generally not exceed distance between transects. Transect sampling should be extended as necessary to include collection and observation of additional samples in all directions from any sampling location where MGP contaminated sediments are observed in surficial sediment. This information will be used to estimate the lateral extent of the surficial contamination.

To determine if there are any potential sources of MGP site-type contaminants originating upstream of the MGP site, comparable sampling should be done at a point or along a transect at some distance upstream from the site.

Sampling of surface sediments along transects should begin in areas "upstream" of the MGP site and then proceed from the downstream end of the proposed sampling area (assumed to be least contaminated) to areas adjacent to the MGP site (assumed to be most contaminated). The downstream-

most transect should be designed to be free of visible MGP site-related contamination. If contamination is observed when sampling this transect, another more downstream transect should be established and sampled. Transects should be established and sampled downstream until all samples from the most downstream transect indicate no contamination as evidenced by the field characterization described in Section 5.5. After the downstream end of contamination is defined, sampling along transects back toward the MGP site can be continued.

Sediment Cores. WDNR recommends that initial field sampling include sediment coring to estimate the vertical extent of contamination at, or in the vicinity of, all locations where MGP site-related contamination is observed in surficial sediments. In addition, some locations where MGP site-related contamination is not observed in the surficial sediments should be investigated by core sampling to determine whether or not any visible contamination occurs at depth. The number and location of sediment cores collected during the initial field investigation should reflect a balance between the limited objectives of this phase of the study and the need to collect information that can help to design a specific plan for sediment sampling and analysis during the detailed field investigation.

Core sampling devices that might be used to collect these samples include gravity corers, vibracorers, or piston corers. Sediment cores should provide representative samples of the vertical profile of unconsolidated sediments. Typically, cores up to three feet will be sufficient. However, if much deeper unconsolidated materials are observed via "soft" sediment mapping and/or the material at the end of the sediment cores appears contaminated, greater lengths may be required. If a three-foot core is not obtained although appropriate sampling gear are used, possibly because only shallow unconsolidated deposits or tight clays were encountered, the investigation report should indicate the apparent reason for the short core lengths.

5.4 Locating Sediment Mapping and Sampling Locations

Although the objective of the initial field investigation is not to develop a detailed characterization of spatial variability of contaminant concentrations across the study area, it is still important to precisely locate and control sediment mapping and sampling locations in this phase of the assessment. Initial field investigation mapping and sampling sites should be located as precisely as is practicable to ensure that data from this initial investigation will be fully useable and to assist in the design of additional sampling efforts.

Depending on site conditions, it may be appropriate to locate mapping and sampling sites by range-bearing, range-range, triangulation, or global positioning techniques. For many purposes, the initial investigation sampling locations can be described based on their location relative to a project-specific control point. At some point in time, the precise location of this control point should be determined so that these positions can be described in some external (to the project) geographic coordinate system. As a general rule, the best achievable precision for position locations should be acquired regardless of the method used although sub-meter level work is not typically needed.

5.5 Field Characterization of Sediments

Unconsolidated sediments in the vicinity of the MGP site should be described based on field observation of surficial sediments and sediment cores collected during the initial field investigation and any relevant information developed through sediment mapping. Upon retrieval and visual observation of the sediments, the following characteristics should be noted in a field log book or on field sheets:

- Color (e.g., based upon the Munsell color notations);
- Qualitative description of odor;

- Organic vapor concentrations (e.g., from HNu or OVM readings) as a measure of volatile compounds which may be present in and emitted from the sediments;
- Texture, including notes on the presence and proportions of fine material (i.e. silt or clays), sand, gravel, wood chips, plant fibers, coal, cinders, ash, stones, and other debris;
- Presence, proportions, and character of visible oils and tars;
- Presence of sheens on the water surface after bringing the sample up through the water column;
- Presence of smeared oils or oily coatings on sampling devices;
- Presence/absence of benthic invertebrates in the sediment materials and numbers and identities, if possible; and
- Sediment structure such as plasticity, moisture content, and presence of strata.

For core samples, the thickness of any substrata observed in the core should be recorded along with depth of penetration of the core into the sediments (if available) and lengths of retrieved sediment cores within the core tube.

Caution should be used in handling sediments that may contain volatile compounds, PAHs, cyanide, and metals. Inhalation of cyanide and VOCs may pose a risk to worker health. A health and safety plan for the entire site sampling effort should establish the appropriate level of protection.

5.6 Chemical and Physical Characterization of Sediments in the Initial Field Investigation

A subset of the sampled surficial sediments and sediment cores should be subjected to laboratory analysis to determine chemical and physical character. The subset of samples selected for laboratory analysis should represent the range of conditions observed in this stage of the site investigation: surficial and lower strata, visually contaminated materials and materials that show no apparent contamination.

The design for the initial field investigation should identify the number of samples to be characterized by laboratory methods, the approach for defining segments within sediment cores, and the approach to be used to determine which samples will be submitted for analysis. The number and location of samples to be analyzed in the laboratory during the initial field investigation should be sufficient to unequivocally answer the question of whether MGP site-related contaminants are present in sediments of the water body at levels that (potentially) threaten the aquatic ecosystem or human health. This objective should be balanced with the recognition that this is only an initial investigation, and if it is indicated, further detailed investigation will follow. As a general rule, WDNR recommends that approximately 20 to 50 percent of all dredge and core samples collected be quantitatively characterized by laboratory analyses. The lower end of this range may be appropriate if field screening analyses (described below) are conducted.

Sediment cores can be subsampled by segment defined by visible strata or, if these are lacking, by predetermined depth increments. The upper 10 or 15 cm segment of sediment core is typically considered to represent surficial, biologically active conditions. Lower segments should typically range from 30 to 60 cm in length. Visible strata less than 10 cm thick generally should not be separately sampled.

WDNR recommends that screening-level indicator analyses be used to help identify samples for laboratory analysis and to maximize the number of characterizations that can be accomplished in the initial field investigation. Screening-level methods that may be appropriate for MGP site

investigations include immunoassay analysis or fluorescence spectroscopy for PAHs, organic vapor analysis by flame ionization or photoionization detector, or field portable gas chromatography for relatively volatile components of MGP wastes. Some potentially applicable field screening methods are briefly discussed in the companion document, "Guidance for Analytical Characterization of Sediment, Soil, and Surface and Ground Water at Manufactured Gas Plant Sites." (WDNR, in draft)

Screening-level indicator analyses can be (1) a direct measure of sediment composition or contamination or (2) an indirect measure of sediment quality which may be related to the parameters of concern at the site. The value of indicator analysis is that it may reduce per unit analytical costs relative to conventional laboratory analysis and, therefore, allow tests to be conducted on a larger number of samples. The actual number and balance of indicator analyses and conventional laboratory analyses performed may depend on a number of factors that are site-specific, including preliminary indications of the areal and vertical extent of contamination.

If indicators analyses are used, both indicator and conventional analysis will need to be carried out on selected samples to determine how well the indicator and conventional results correlate. Decisions to use indicator analysis or an abbreviated parameter list for some samples should consider:

- Environmental relevance of the proposed analysis and alternative analyses;
- Regulatory requirements;
- Analytical costs;
- Analytical production rate and sample turnaround time (i.e., time elapsed between sampling and analytical reporting); and
- Potential for correlation with conventional chemical analysis.

Using either field screening analyses or simple visual and olfactory indicators of contamination, samples can be assigned to a contamination category. The subset of samples for laboratory analysis should include representatives from each contamination category. See the separate analytical guidance for information about the types of analyses that should be run on samples from MGP sites.

5.7 Site Management Issues

All investigative waste, such as contaminated sediment cuttings and decontamination waste, from MGP-contaminated or suspected MGP-contaminated areas should be collected, segregated, contained, stored, and disposed in an appropriate manner. A management plan for investigative waste must be included as part of the work plan. Refer to WDNR's general interim guidelines on investigative waste management (Bureau of Solid and Hazardous Waste Management, January 14, 1993) for information on WDNR recommendations and requirements for investigative waste management.

Because of the potential for probing and coring activity to disturb and release coal tars or oils to the water column, a floating oil absorbent boom or other absorbent materials should be ready to be deployed in the area where the sediment sampling activity will be taking place. All reasonable efforts should be made to contain and collect any slicks or oils that appear on the water surface.

If a casing is used in sampling sediments, all completed off-shore borings must be back-filled with bentonite chips from the bottom of the boring to the sediment surface as the casing is withdrawn from the boring. The boreholes shall be abandoned as required in s. NR 141.25. Wis. Adm. Code.

5.8 Initial Site Investigation Report

The results of the initial field investigation shall be presented in a report as required in s. NR 716.15, Wis. Adm. Code. This report shall include:

- Background information;
- Methods of investigation;
- Results;
- Visual aids, including maps;
- Sediment core and grab sample documentation; and
- Conclusions and recommendations.

This report shall be submitted to WDNR. If WDNR is actively overseeing this project, this report will be subject to WDNR review and approval.

The conclusions and recommendations section of the report should indicate whether MGP site-related contamination was observed and describe further response actions that may be necessary to protect public health, safety and welfare and the environment. The conclusions and recommendations should be based on evaluations of the available information by the approaches described in Chapter 7. Contaminant concentrations in aquatic sediments should be evaluated with respect to reference site concentrations and effect levels (determined by other agencies' established guidelines or sediment quality objectives calculated for the protection of water quality criteria or fish tissue residue guidelines).

If in the course of the initial field investigation, MGP site-related contamination is observed (e.g., study area concentrations are elevated above relevant background concentrations) *and* appropriate guidelines for the evaluation of sediment quality (as recommended by the department) are exceeded, a detailed field investigation to determine the nature, degree, and extent of contamination should be recommended. If no MGP site-related contamination is observed or no effect-based SQOs are exceeded and if there is no other evidence of current or potential impacts to sediment, the investigating party may recommend to WDNR that no further sediment investigation be conducted as part of MGP site management.

6. Detailed Field Investigation

Based on the results of the initial field investigation, investigating parties or WDNR (if WDNR is actively overseeing the project) will determine whether or not to proceed with a more detailed investigation. Generally, a detailed field investigation should be planned and conducted if the initial investigation indicates that MGP site-related contaminants are present in the sediments at concentrations that may significantly threaten the aquatic ecosystem or human health. The scope of the detailed investigation will depend on the findings of the initial investigation.

The following sections discuss the design of a detailed field investigation, activities typically involved in a detailed field investigation, and the required contents of an investigation report. Site management issues are discussed above in Section 5.6; the information in that section is also applicable for detailed field investigations.

6.1 Design of Detailed Field Investigation

The objectives of a detailed field investigation are to (1) characterize, as completely as possible, the three-dimensional (areal and vertical) distribution of MGP contaminants in sediment deposits of the water body associated with the former MGP site and (2) provide information to support the evaluation of remedial action options appropriate for the observed nature and severity of contamination. Specifying a sampling pattern or the number of samples needed to adequately characterize the sediments at all MGP sites is not possible. The appropriate design will depend on the level of information developed in the initial investigation and the remaining data needed to fully characterize the sediment contamination at the site.

Typically, detailed investigations will entail enhanced areal and vertical characterization of sediment contamination and evaluation of biological and/or water column impacts of sediment contaminants. In some cases, sediment mapping will also be enhanced in the detailed field investigation.

To establish a site-specific plan for detailed investigation, the results of the initial investigation should be evaluated and data gaps identified. The amount of sediment coring and sample analysis needed to characterize the site should be compatible with the precision needed to evaluate and design any remediation of sediments at the site. In the case that remediation is needed, the costs of an appropriately detailed site sampling program can reduce overall project costs by precisely delineating "clean" and contaminated sediments, thus allowing the remediation to be focused on the materials of greatest concern. In previous deteailed sediment investigations conducted by or overseen by WDNR, sampling densities ranging from one core for each 250 to 4,700 m^2 of sediment surface area have been used to characterize contaminated areas. (These densities represent, for example, systematic sampling centered in 16 to 70 meter square grid cells.)

Additional sediment mapping, if needed to assist with study design, might be conducted as a preliminary step in the detailed field investigation. Information on the quantity and physical character of sediments can be very useful in designing a sampling network and in estimating the scope of a potential remediation project.

Beyond sediment contaminant characterization, the detailed investigation might also include ecological assessment field work or sampling and evaluation of surface water. The design of the detailed investigation should clearly identify and describe a proposed approach for evaluating the significance of sediment contamination. Chapter 7 provides information on various approaches that might be used to evaluate sediment contamination, including site-specific assessments of ecological threats and impacts. Water column analysis, especially

of that portion of the water column most directly affected by MGP contaminants may be needed to assess contaminant release, availability, concentration, and dispersion.

As with the initial site investigation, a work plan should be prepared for the detailed field investigation. Work plan requirements are discussed in Section 4.4 and enumerated in s. NR 716.09(2), Wis. Adm. Code. If WDNR is actively overseeing this project, the work plan should be submitted to WDNR for review and approval prior to conducting any detailed field investigation activities.

6.2 Mapping Sediment Deposits

The design for a detailed investigation of sediment contamination is based in large part on characterizations of the location and thickness of unconsolidated aquatic sediment deposits in the vicinity of the MGP site. Initial sediment mapping and sediment observation and analysis from the initial investigation are principal ingredients in the design of a sampling plan for the detailed investigation. An additional mapping effort may be required to enhance the information from the initial investigation if the areal and/or vertical extent of soft sediments in the vicinity of the MGP site have been incompletely characterized. Approaches to mapping sediment deposits are discussed in Section 5.2.

If detailed sediment mapping was conducted in the initial investigation, additional mapping may not be needed. As discussed below, detailed investigations will typically entail some deep sediment coring. Characterizing depths of sediments to a native (assumed clean) substrate can be an important piece of information for "ground truthing" or validating sediment maps developed from remote profiling techniques and/or sediment probing.

6.3 Sediment Sample Collection

In detailed field investigations, sediment cores should be collected for field characterization and laboratory analysis. Cores should encompass the longer of (1) the biologically active zone, (2) the depth of resuspendable sediments, or (3) entire depth of observable contamination. At some sites contamination may occur at considerable depth and it may not be practicable to develop cores of the total depth of contaminated sediment at each coring location. If necessary to limit the magnitude of the project, it may be reasonable to sample the entire depth of observable contamination at only a subset of the coring locations.

The work plan for the detailed investigation should describe the equipment and procedures that will be used to collect sediment core samples. Where sediments or contaminants are quite deep (e.g, greater than about 3 feet), drilling or coring equipment mounted on a suitable sampling platform may be needed to develop cores of the entire length of contaminated sediment.

6.4 Locating Sampling Positions

As in the initial field investigation, it is important to precisely locate and control sediment mapping and sampling locations in this phase of the assessment. Field investigation mapping and sampling sites should be located as precisely as is practicable to ensure that data will be fully useable (e.g., in GIS or CAD applications) and documented.

Absolute positioning is required to tie sampling positions to a geographic coordinate system. This may be accomplished with land surveying techniques or geopositioning procedures. Sampling locations should be defined within plus or minus three feet and should utilize the State Plane Coordinate System or an alternative system that is acceptable to WDNR. All elevations should be referenced to appropriate National Geodetic Vertical Datum.

6.5 Field Characterization

Sediment cores collected in the detailed investigation should be characterized as described in Section 5.5. The goal of this characterization is to document the nature of sediments in the study area and provide

information which may be useful in characterizing site contamination and/or evaluating potential remedial technologies.

Caution should be used in handling sediments that may contain volatile compounds, PAHs, cyanide, and metals. Inhalation of cyanide and VOCs may pose a risk to worker health. A health and safety plan for the entire site sampling effort should establish the appropriate level of protection.

6.6 Chemical and Physical Analysis of Sediment Samples

The number of samples to be developed for chemical and physical characterization and the procedures for subdividing retrieved cores for analysis of the pollutants of concern should be established in the work plan for the detailed investigation. As a general guide, WDNR recommends the following design elements:

- Representative sections not more than 60 cm long from throughout the retrieved core should be selected for analysis. Where identifiable strata are found within the core, the strata material should be sampled and analyzed.

- The 0 to 30 cm surficial segment (measured down from the sediment surface) in all cores should be analyzed.

Sediment samples identified for chemical and physical analysis should be analyzed for the pollutants of concern based on the results of the initial investigation. The work plan should specify a set of chemical analyses, including, as appropriate, screening-level indicator assays (e.g., Microtox) and/or analyses (e.g., PAH analysis by fluorimetry). See the analytical guidance for MGP site investigations for more information on parameter selection and analytical methods. WDNR recommends that detailed field investigations make use of laboratory analyses to a greater extent than indicator analyses (which may make up the majority of the analytical effort in the initial investigation).

6.7 Site-Specific Ecological Assessment and/or Water Column Analysis

Investigators may assess site-specific impacts to ecological receptors or the water column as part of the detailed field investigation. In many instances, field efforts to measure ecological threats and/or the transport or impacts of contaminants in the water column will be performed to evaluate the implications of MGP site-related sediment contamination on the aquatic system. WDNR recommends that site-specific evaluations of the impacts and transport of sediment contaminants be used where practicable to provide the data needed to support site management decisions.

Approaches to evaluating sediment quality data are discussed in Section 7. As discussed in that chapter, it is WDNR's preference that site-specific data be developed to minimize the uncertainty in site management decisions. Because most MGP site-related contaminants are not substantially bioaccumulated up the food chain, threats and impacts will tend to be greatest in the locally contaminated area or in downstream areas where benthic and water column organisms are exposed to relatively high concentrations of contaminants in the sediment or surface water. Site-specific investigations of impacts and/or transport should be designed to quantitatively characterize the threats to the most sensitive receptors receiving the highest exposures to MGP site-related contaminants.

6.8 Site Investigation Report

The results of the field investigation should be presented in a report to be submitted to WDNR. If WDNR is actively overseeing the project, it is WDNR's responsibility to review and approve this report. This report shall include the contents required by s. NR 716.15, Wis. Adm. Code, and discussed above in Section 5.8.

After all field activities are complete and laboratory reports received, all available data on sediment quality, and ecological impacts and water quality if available, should be used to develop a characterization of the nature and severity of site contamination. Initial data evaluations may be based on comparisons of observed site-related contaminant levels to reference site conditions and to WDNR-recommended SQOs. The approach for evaluating the significance of sediment contamination (e.g., using site-specific ecological assessment, transport calculations or model results) described in the work plan should be followed. Chapter 7 provides information on various approaches that might be used to evaluate sediment contamination.

The conclusions and recommendations section of the report should discuss the need to proceed further with site evaluation and/or remediation. Examples of the types of conclusions that might be made after completion of a detailed field investigation include:

- Site areas with sediment concentrations exceeding SQOs have been characterized and sufficient information is available to recommend a remedial options analysis (consistent with the procedure outlined in s. NR 716.17(3), Wis. Adm. Code); or
- Site areas with sediment concentrations exceeding SQOs have been characterized, but additional information is needed to better characterize areas posing significant threats to the aquatic ecosystem (and its human uses) and it is appropriate to proceed with additional site characterization and/or ecological assessment and remedial options analysis; or
- Sediment concentrations associated with the MGP site do not exceed SQOs and it is appropriate to recommend "no further action" for sediment remediation (consistent with the procedure outlined in s. NR 716.17(4), Wis. Adm. Code).

7. Evaluation of the Significance of MGP Contaminated Sediments

The linkage between the level of MGP site-related contaminants in sediments and decisions about the management and remediation of sediments lies in evaluating the potential risks to humans, wildlife, and aquatic organisms resulting from direct and indirect exposure to any contaminated sediments at the site. Humans, wildlife and aquatic organisms may be exposed to MGP contaminants through various pathways, including ingestion, inhalation, or dermal contact with contaminants in sediments and/or water.

The first step in evaluating sediment quality and making sediment remediation decisions is to develop sediment quality objectives (SQOs). SQOs are typically expressed as contaminant concentrations in the biologically or hydrologically active zone of sediment deposits. SQOs reflect levels of contamination that are protective of all present and reasonably anticipated prospective uses of the aquatic ecosystem at the site of contamination. SQOs typically are developed using simple concentration:effect relationships or steady-state modeling; consequently SQOs often do not consider either the distant effects of contaminants transported from the area under investigation or cumulative effects from multiple areas of contamination. See the discussion at end of this chapter about evaluations of sediment contaminant transport.

Beneficial uses of the aquatic system at the site of contamination that are typically protected in WDNR's SQOs include

- Consumption of fish by recreational and/or subsistence anglers;
- Propagation and health of aquatic life, including benthic macroinvertebrates and fish;
- Propagation and health of wildlife, including piscivorous birds and mammals; and
- Supply of water for consumptive uses, including drinking.

WDNR is developing guidance on contaminated sediment clean-up decisions including the development of SQOs to protect various beneficial uses. That guidance will provide some detailed information about the variety of approaches used by WDNR to determine SQOs; contact WDNR for information on the status and availability of that guidance. The available approaches can be divided into three categories, listed in order of increasing complexity:

- Comparison of contamination levels to conditions at reference sites (i.e., local background conditions);
- Comparison of contamination levels to existing sediment quality guidelines or estimated sediment concentrations needed to protect water quality criteria or fish tissue residue guidelines; and
- Site-specific assessment of ecological threats and impacts.

Most approaches (except determination of reference site conditions) are based on identifying sediment concentrations associated with levels of contamination (e.g., in fish tissue or surface waters) or effects (e.g., toxicity, benthic community alteration) determined to be protective of specific uses. Depending on project and site conditions, WDNR will use a combination of approaches for assessing whether contaminants at their present locations and concentrations or in expected future conditions are potentially responsible for adverse effects to aquatic organisms, wildlife, and/or humans. Using a variety of approaches and numerous endpoints within each approach allows an evaluation of the beneficial uses that are most sensitive to the sediment contamination and to analyze the effects of different SQO development approaches on the determination of protective levels. WDNR prefers to use site-specific approaches when

possible, with information collection occurring during the detailed field investigation.

The release and transport of sediment contaminants from some sites, potentially including some MGP sites, may present a threat that is equal to or greater than the threat posed locally by the "in place" contamination. This possibility should be assessed at each site. If necessary, the significance of sediment contamination in the vicinity of an MGP site should be evaluated via modeling (possibly just steady state calculations) to estimate potential downstream concentrations and effects. If hydrologic, biological, or chemical/physical factors indicate the potential for considerable site-originating effects at downstream locations, sediment remediation decisions should include this information and should not be limited to evaluation of the potential local effects of "in place" contamination.

8. Identifying and Evaluating Remedial Action Options and Selecting Remedial Actions

If after completion of the site investigation and evaluation of the significance of sediment contamination, WDNR determines that remedial action is necessary (per s. NR 716.17, Wis. Adm. Code), the investigating party shall identify, evaluate, and document an appropriate range of remedial action options applicable to contaminated sediments at the MGP site as required by ch. NR 722, Wis. Adm. Code. It is important that the remedial action options be evaluated against the criteria established in ch. NR 722, Wis. Adm. Code.

As part of the remedial action options analysis, the investigating party may need to perform additional studies, especially tests to support hazardous waste determinations (e.g., TCLP analyses) and treatability tests.

The remedial action options report, as required by s. NR 722.13, Wis. Adm. Code, should be submitted to WDNR. If WDNR is actively overseeing the project, it is WDNR's responsibility to review and approve this report.

9. Remediation and Post-Remediation Monitoring

Monitoring may be required during the operational phases of any in-water remediation activities and following completion of remediation activities. Surface water and/or sediment monitoring may also be conducted during any on-land remediation activities.

During remediation, there is a concern that MGP site-related contaminants may be released (from sediments, soils, or ground water) into surface waters. The magnitude of release, transport, and associated risks should be quantified and minimized through an effective monitoring program and decision-making framework. It is envisioned that chemical decision criteria and/or biological decision criteria will be established to define unacceptable increases of chemical constituents or unacceptable biological impact during remedial action implementation. A decision-making framework and process should be established to review data for unacceptable chemical and biological impacts and to assure appropriate actions are taken to modify operations. Real-time monitoring methods will be needed to support decisions about unacceptable impacts during the remedy implementation. The development and use of decision criteria, coupled with real-time monitoring will allow:

- Identifying operational problems during the project,
- Improving operational procedures in a timely manner, and
- Limiting risks associated with the project.

Long-term (post-remediation) monitoring shall be planned and implemented in compliance with the requirements of s. NR 724.17, Wis. Adm. Code, to determine the effectiveness of any completed remedial action in meeting the remedial objectives established for the project and the recovery and restoration of the resource.

10. Case Closure

Following documented attainment of sediment quality objectives in a site investigation report or following implementation of a remedy, an investigating party may request case closure as indicated in ch. NR 726, Wis. Adm. Code. A site with sediment contamination in a surface water is classified according to s. NR 700.09, Wis. Adm. Code, as a "complex site." Therefore, the case closure process involves a request by the investigating party and a decision by WDNR as to whether the case can be closed. WDNR's decision will be based on the information provided in the case closure request and will follow the criteria and process required in s. NR 726.05, Wis. Adm. Code.

11. Bibliography

Cleland, J.G. 1981. Environmental hazard rankings of pollutants generated in coal gasification processes. EPA Project Summary. EPA-600/57-81-101.

Falkenberg, J.A. and C.T. Boesen. 1993. Risk management of remedial actions and the interpretation of soil clean-up criteria -- case studies. In "Developing cleanup standards for contaminated soil, sediment, and groundwater. How clean is clean?" Specialty Conference Series Proceedings. July 10-13, 1993. Washington, D.C. U.S. EPA and Agency for Toxic Substances and Disease Registry.

Helsel, R.W. and D.E. Brandt. 1991. Assessment of selected technologies for remediation of manufactured gas plant sites. Prepared for Electric Power Research Institute (EPRI) by IT Corporation.

Lee, L.S. P. Suresh, C. Rao, and I. Okuda. 1992. Equilibrium partitioning of polycyclic aromatic hydrocarbons from coal tar into water. *Environmental Science and Technology*. 26:2110-2115.

Mills, W.B. 1993. Development of soil cleanup levels at a former manufactured gas plant site in Sacramento, California. In "Developing cleanup standards for contaminated soil, sediment, and groundwater. How clean is clean?" Specialty Conference Series Proceedings. July 10-13, 1993. Washington, D.C. U.S. EPA and Agency for Toxic Substances and Disease Registry.

Mueller, J.G., P.J. Chapman, and P.H. Pritchard. 1989. Creosote-contaminated sites. *Environmental Science and Technology*. 23:1197-1201.

Persaud, D., R. Jaagumagi, and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Water Resources Branch. Ontario Ministry of the Environment and Energy.

Rostad, C.E., W.E. Pereira, and M.F. Hult. 1985. Partitioning studies of coal-tar constituents in a two-phase contaminated ground water system. *Chemosphere*. 14(8):1023-1036.

Smith, J.R. and J.E. Bratina. 1989. An overview of treatment technologies applicable to coal derived contaminated waters and wastewaters. In Proceedings of 1989 Symposium on Biological Procession of Coal and Coal-Derived Substances. Prepared for Office of Exploratory Research, Electric Power Research Institute.

U.S. EPA. 1988. U.S. Production of Manufactured Gases: Assessment of Past Disposal Practices. Office of Research and Development. Hazardous Waste Engineering Research Laboratory. Cincinnati, OH. EPA/600/2-88/012.

WDNR. 1992. Guidance for assessing ecological impacts and threats from contaminated sediments. Publ-WR-321-93.

WDNR. 1992. Background document on assessing ecological impacts and threats from contaminated sediments. Publ-WR-322-93.